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[54] **METHOD FOR MAKING DEFORMABLE COMPOSITE STRUCTURES AND ASSEMBLING COMPOSITE ARTICLE**

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Related U.S. Application Data

[63] Continuation-in-part of application No. 08/651,621, May 21, 1996, Pat. No. 5,800,749, and a continuation of application No. 08/345,899, Nov. 28, 1994, abandoned, and a continuation-in-part of application No. 08/181,321, Jan. 14, 1994, Pat. No. 5,429,066.

[51] **Int. Cl.**⁷ **B29C 44/06**

[52] **U.S. Cl.** **264/46.4; 264/46.6; 264/257; 264/258; 264/273**

[58] **Field of Search** **264/46.4, 46.6, 264/258, 273, 46.5, 257; 425/812**

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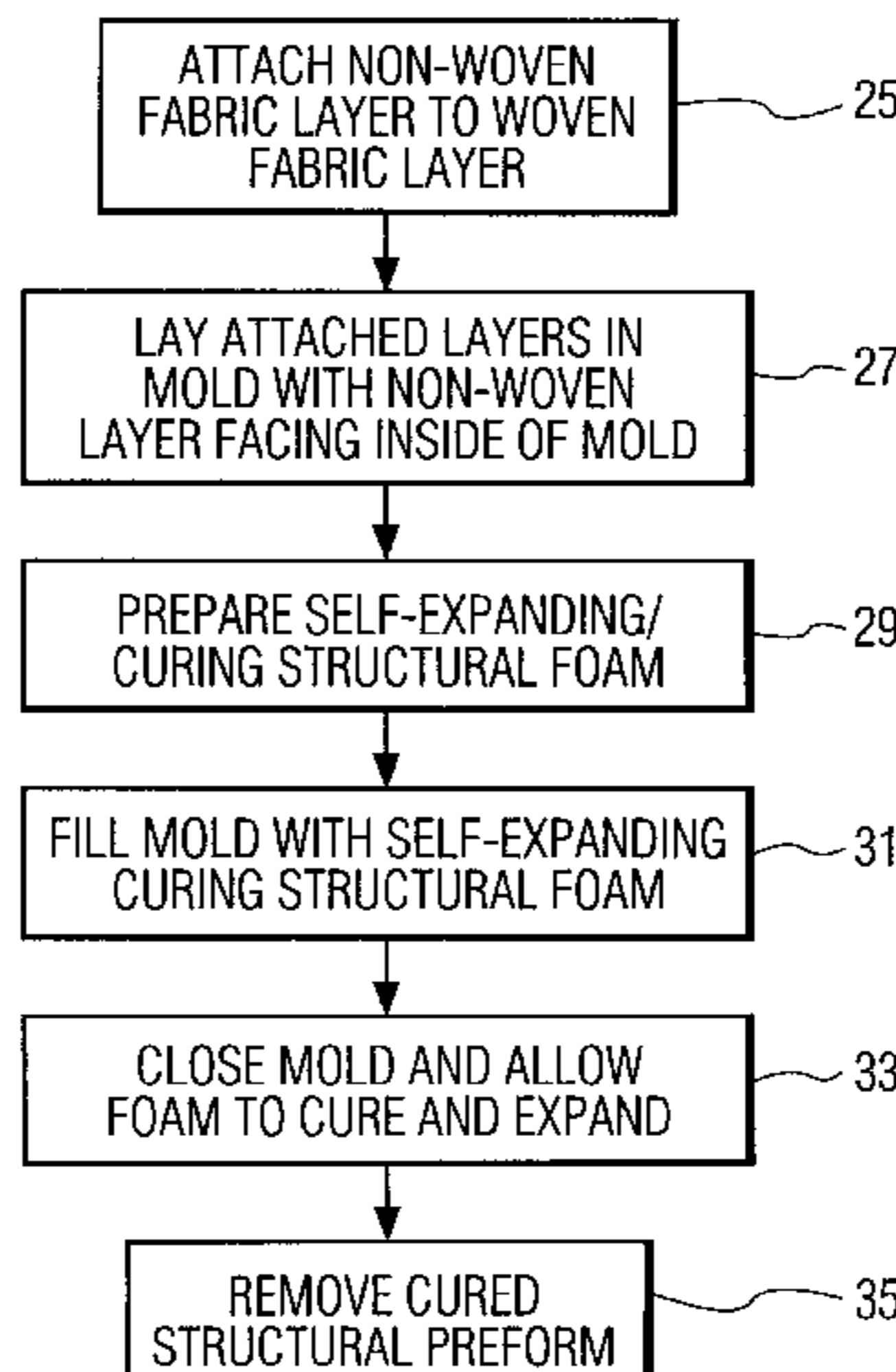
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[57] **ABSTRACT**

A method of making a resilient composite structure having an exposed reinforcing fabric layer free of structural foam and curable resin and for manufacturing a composite article utilizing the resilient composite structure. The method for manufacturing a composite article includes the steps of positioning at an attachment point within the first plastic shell a resilient foam core composite structure having an exposed reinforcing fabric layer attached to a non-woven fabric layer on one side thereof, the resilient foam core substantially filling interstices of the non-woven fabric layer, without substantially penetrating the reinforcing fabric layer; saturating said reinforcing fabric layer with a curable plastic resin; positioning said second plastic shell on said first plastic shell so that said resilient composite structure contacts an attachment point of said second plastic shell and is compressed between the plastic shells; and allowing said plastic resin to cure.

4 Claims, 6 Drawing Sheets



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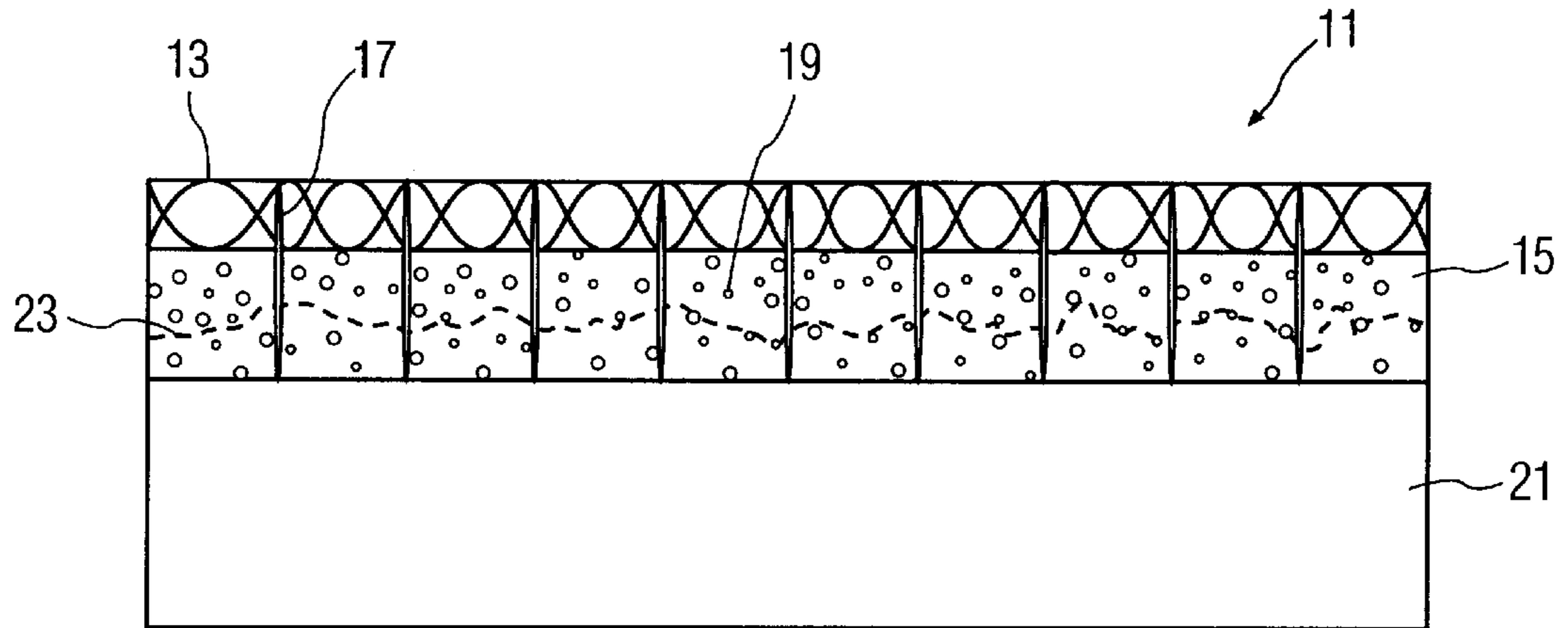


FIG. 1

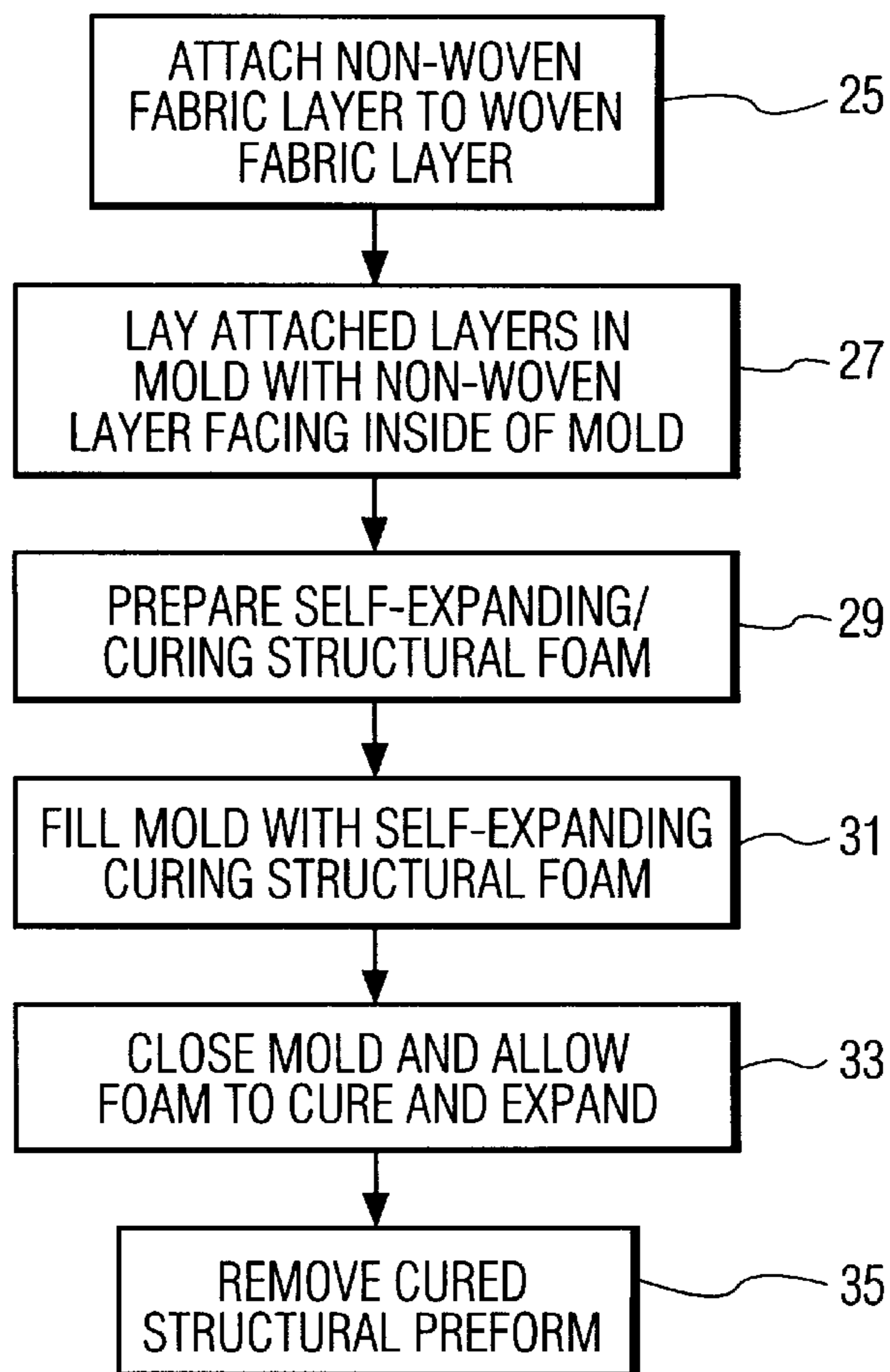


FIG. 2

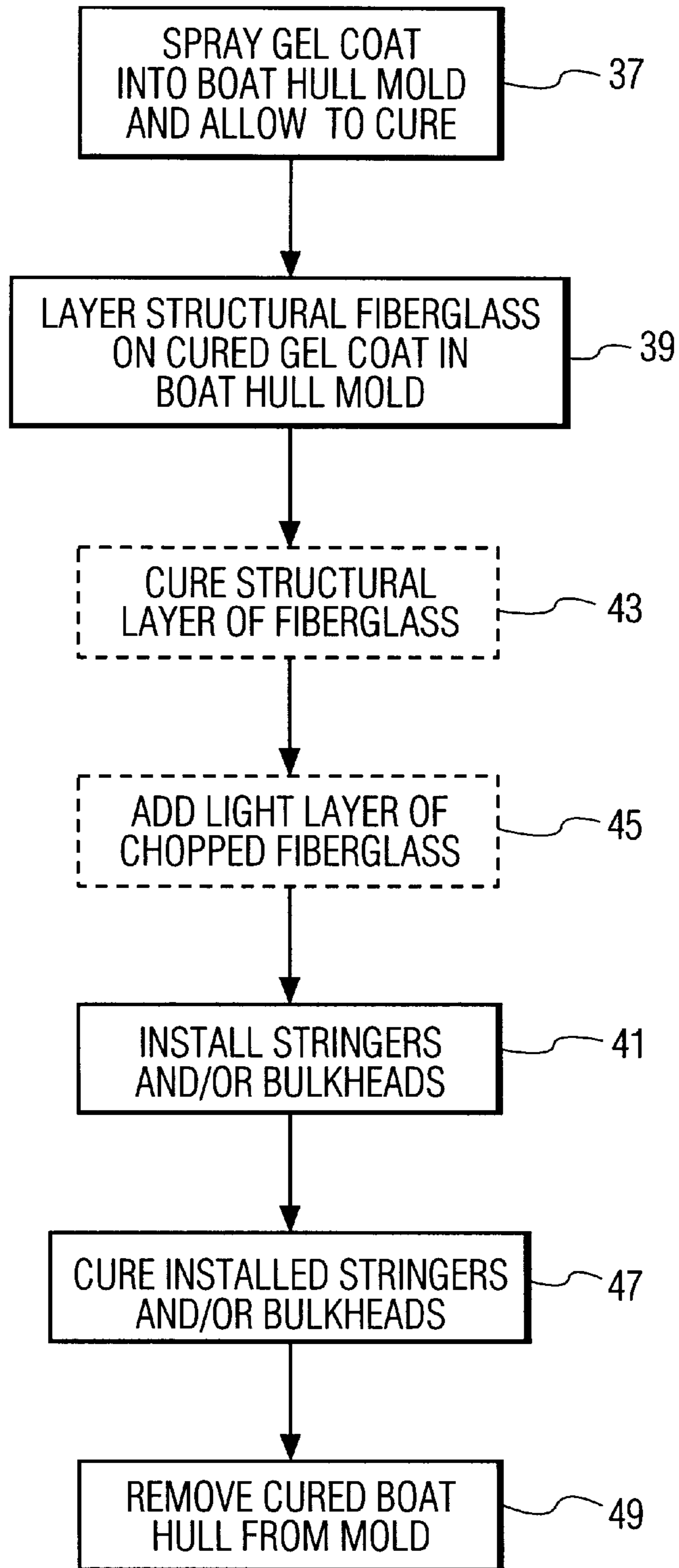


FIG. 3

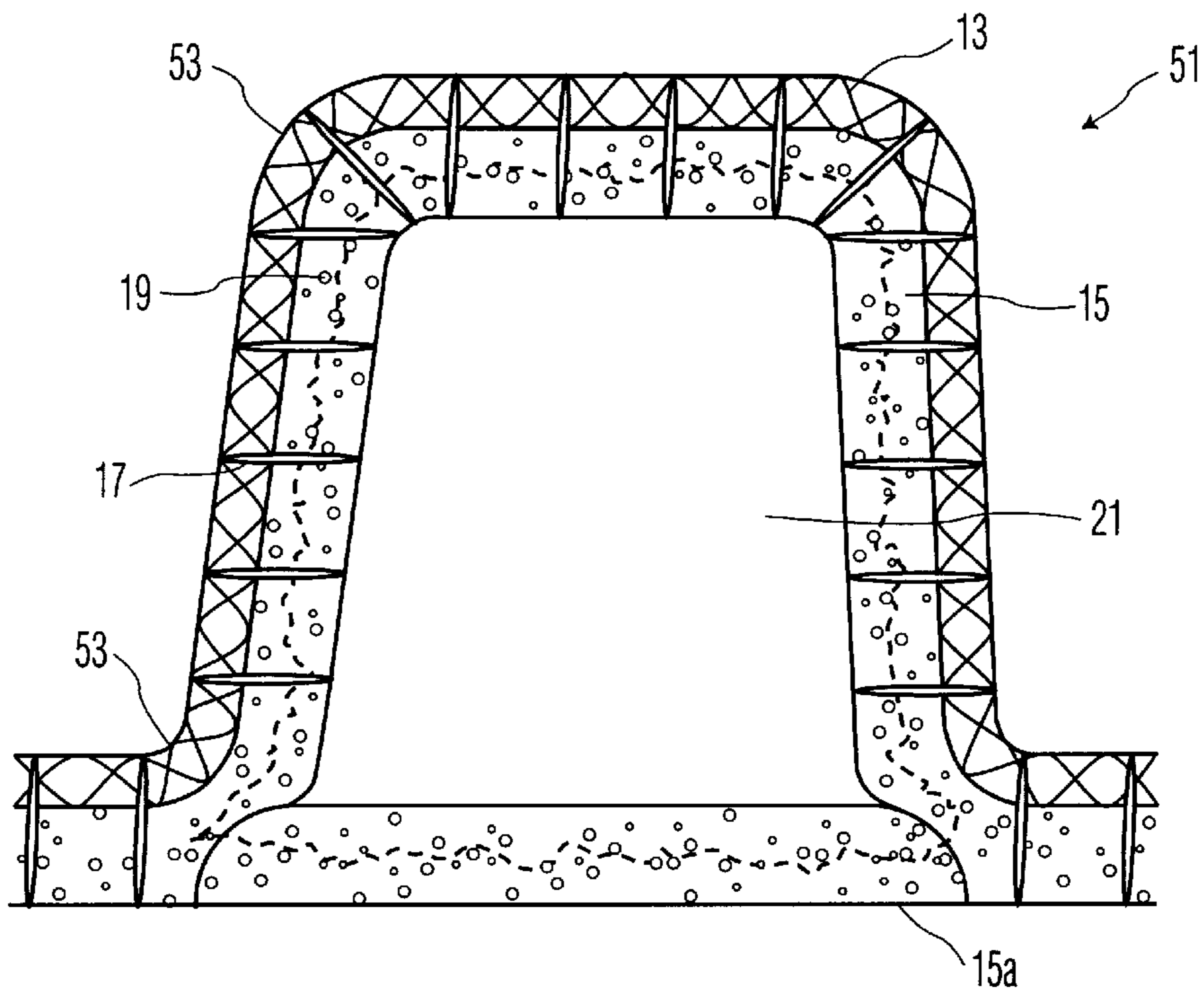


FIG. 4

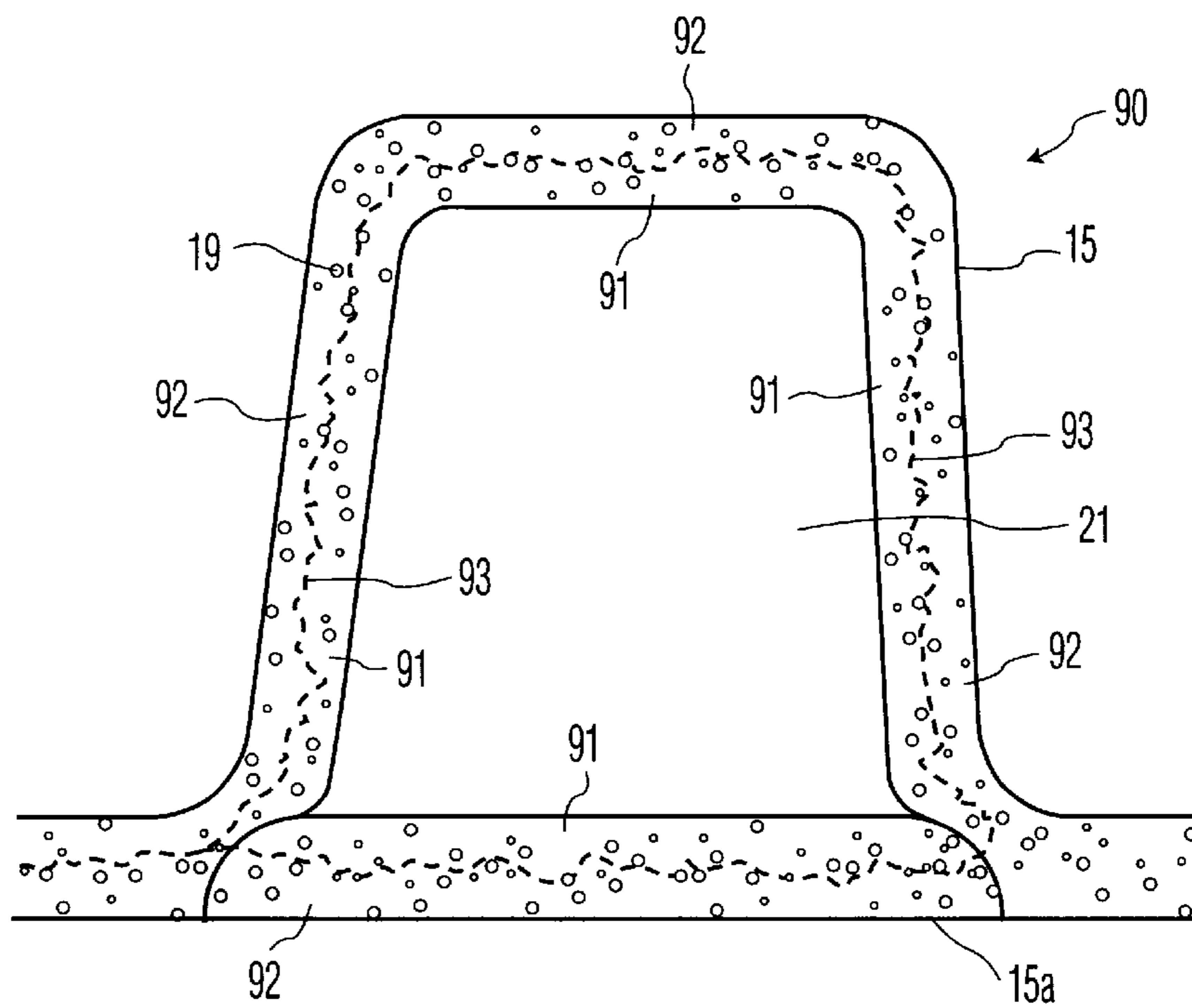


FIG. 5

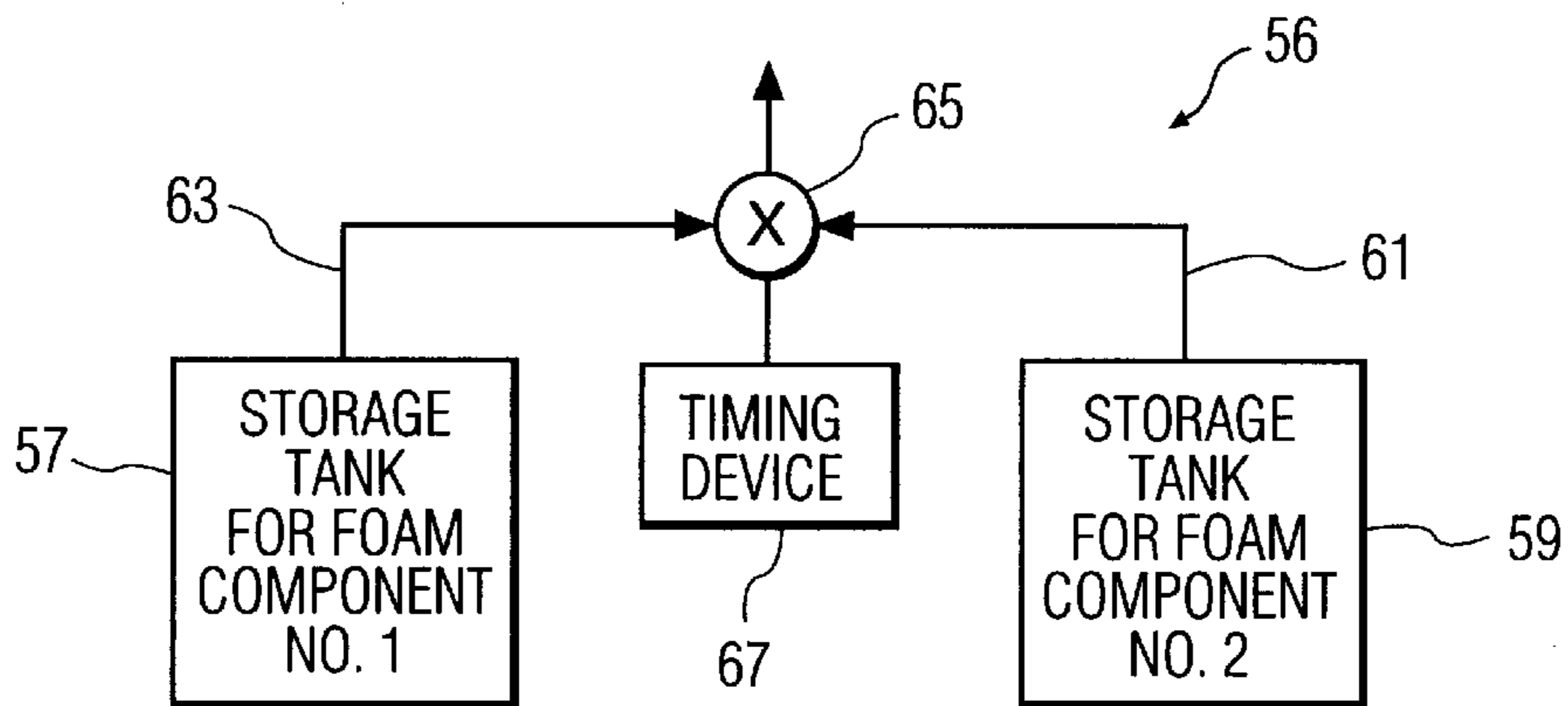


FIG. 6

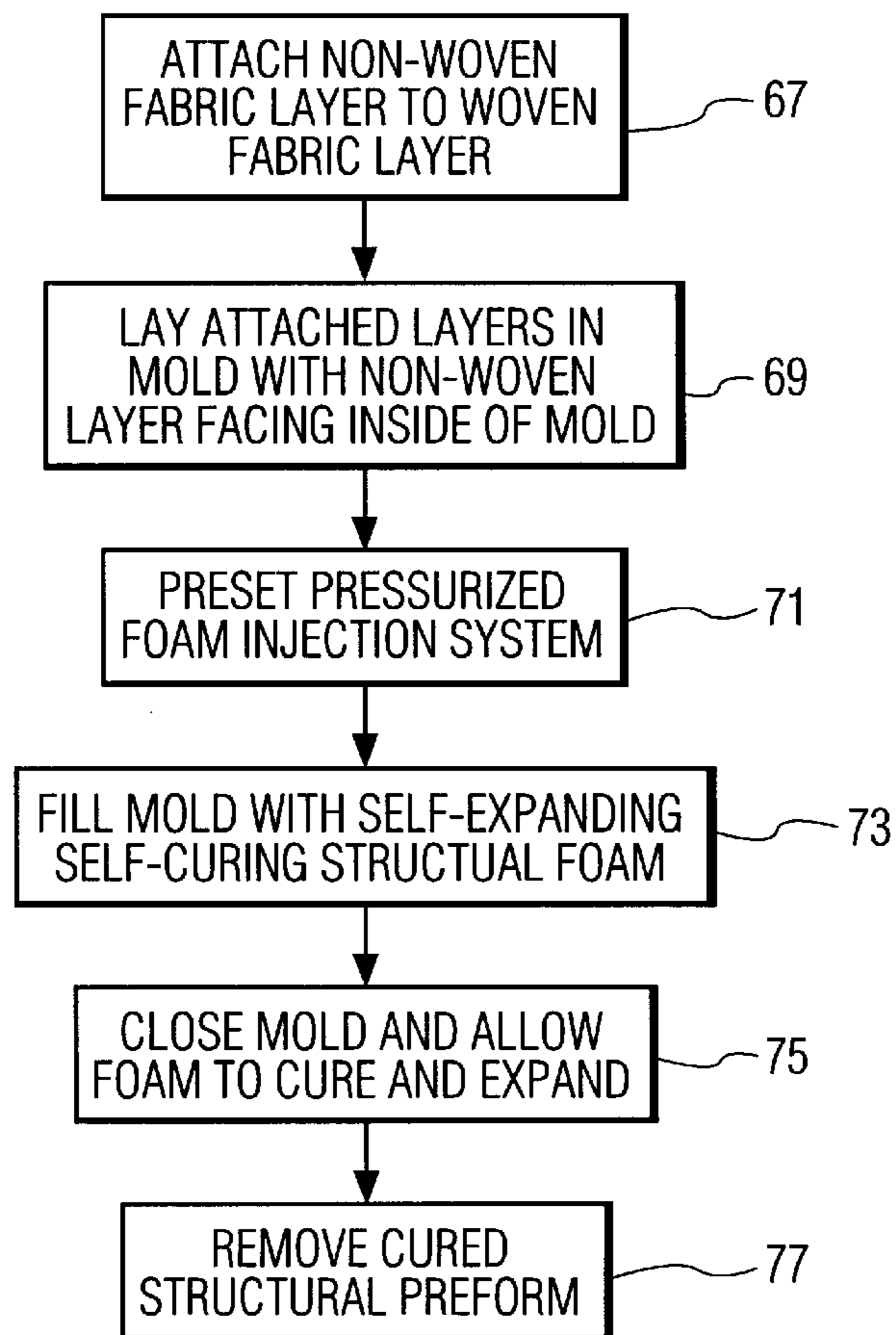


FIG. 7

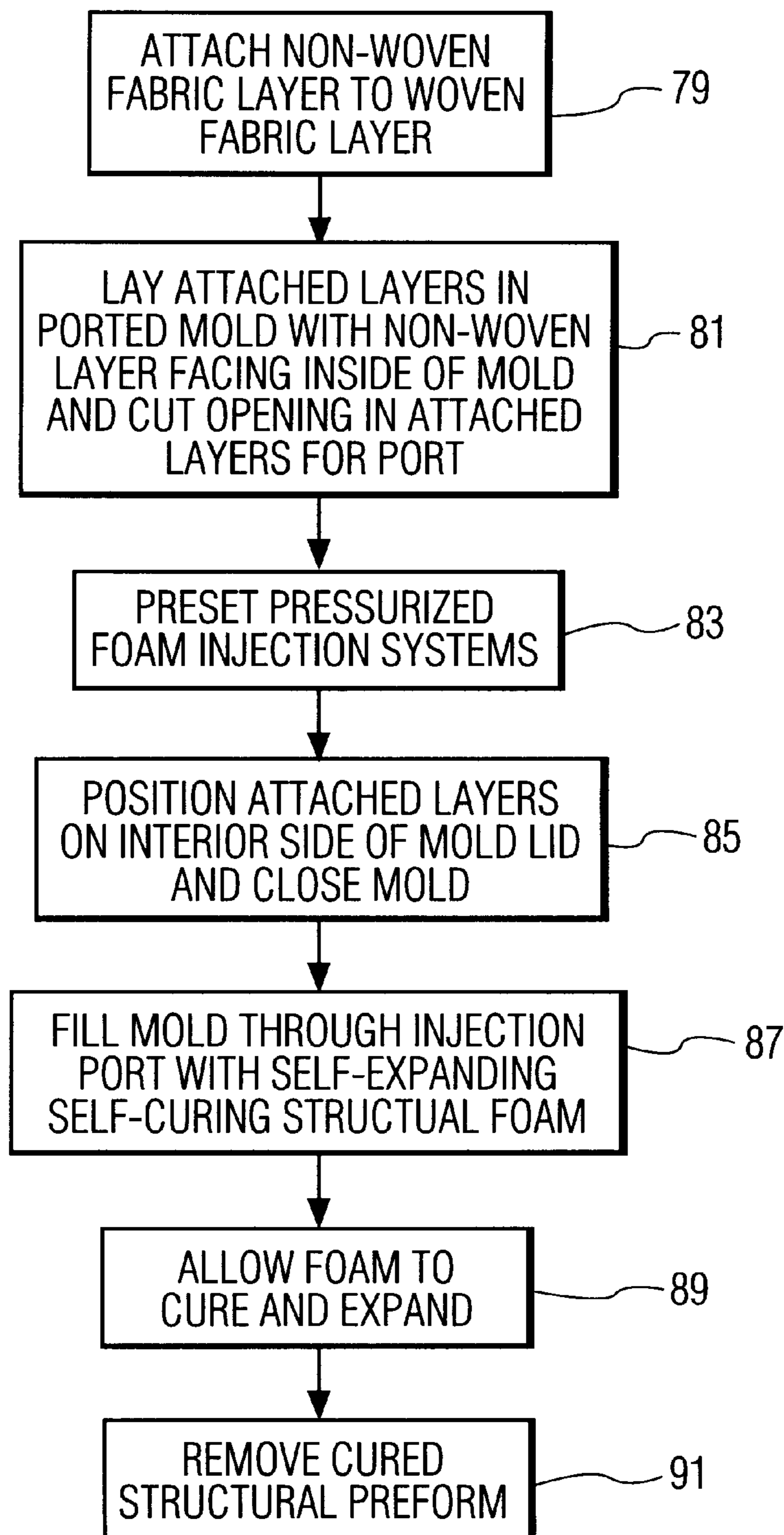


FIG. 8

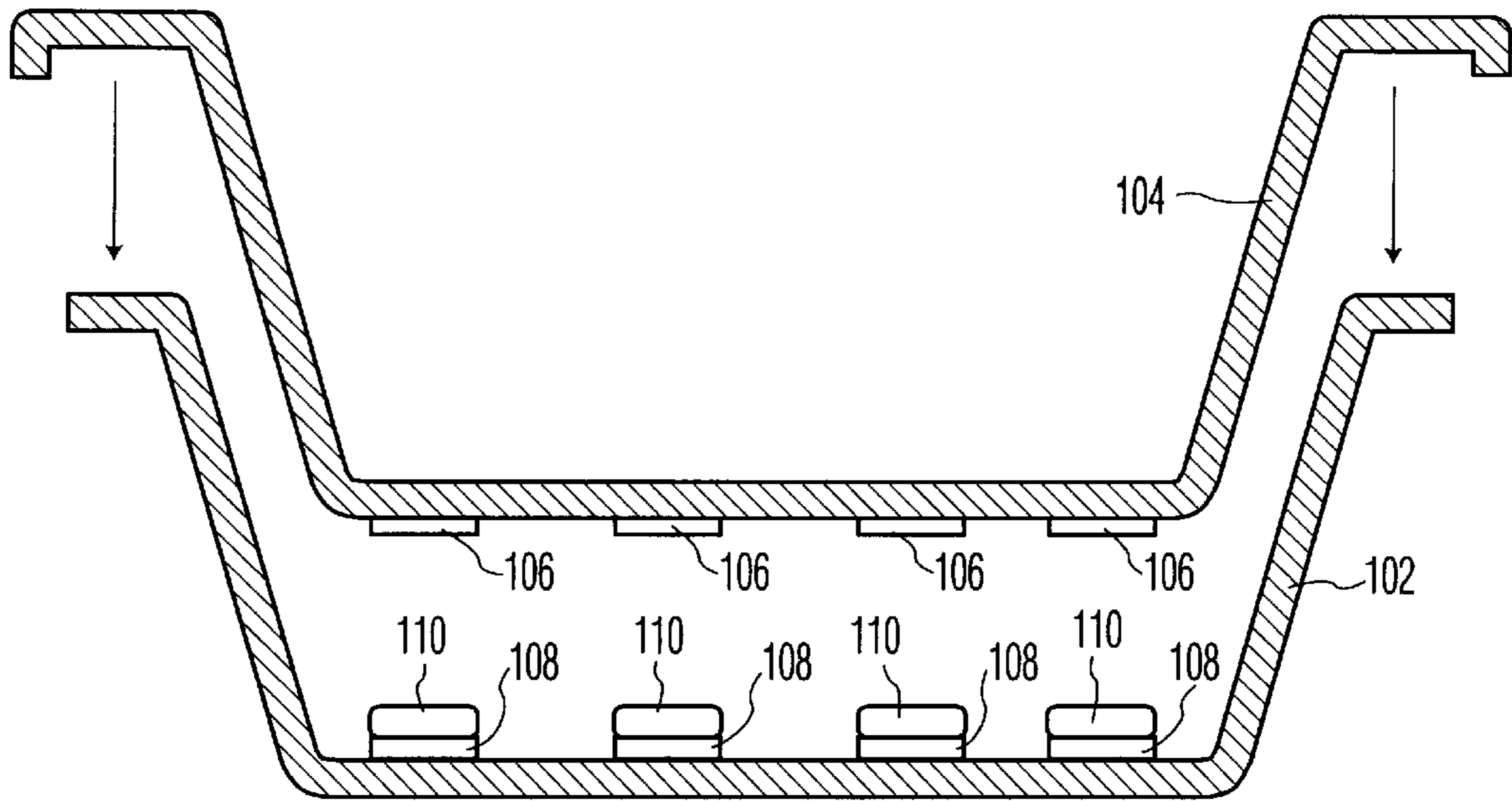


FIG. 9

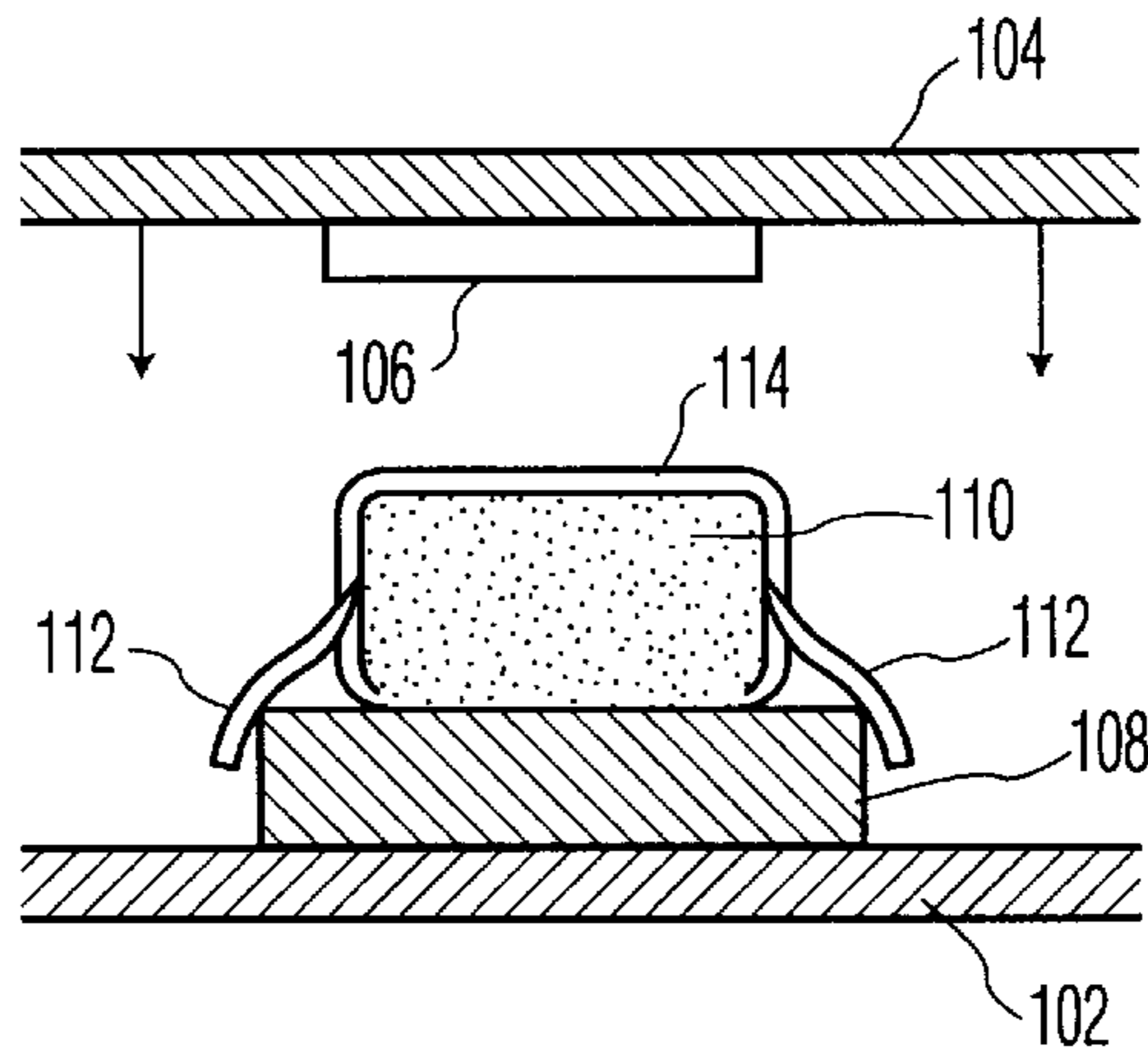


FIG. 10a

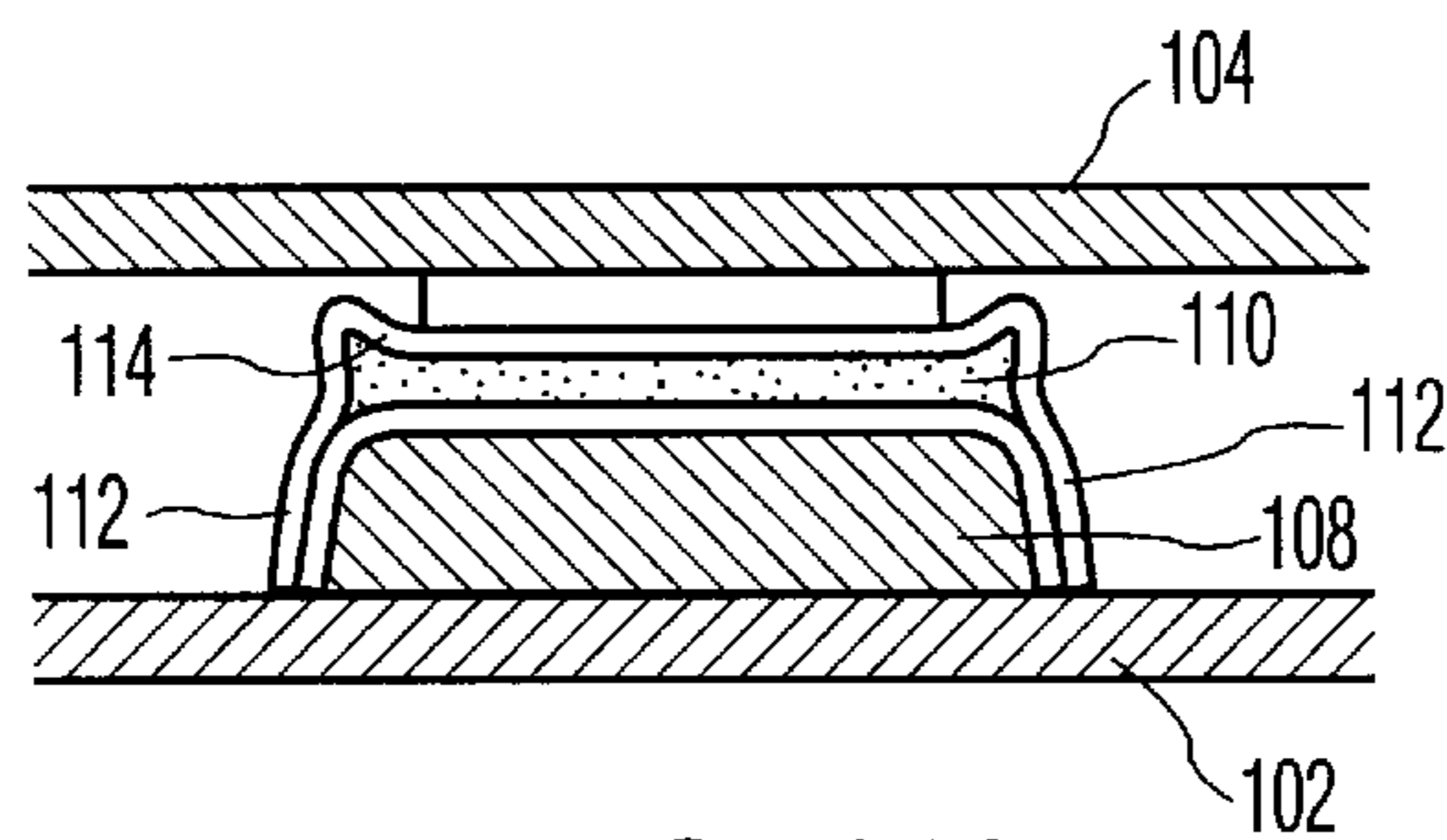


FIG. 10b

**METHOD FOR MAKING DEFORMABLE
COMPOSITE STRUCTURES AND
ASSEMBLING COMPOSITE ARTICLE**

**CROSS REFERENCE TO RELATED
APPLICATION**

This application is a continuation-in-part of application Ser. No. 08/651,621, filed May 21, 1996, now U.S. Pat. No. 5,800,749. Application Ser. No. 08/651,621 is a continuation of application Ser. No. 08/345,899, filed Nov. 28, 1994 now abandoned. Application Ser. No. 08/345,899 is a continuation-in-part of application Ser. No. 08/181,321, filed Jan. 14, 1994, now U.S. Pat. No. 5,429,066.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a composite structure and method of making composite structures. More particularly, the invention relates to resilient composite components which are especially adapted for use in blind connections between two or more composite shell members, and a method for manufacturing a composite article using said resilient composite components.

2. Description of Related Art

In the past, a number of structural composite articles have been developed using a variety of different technologies. One prior art technique involves interweaving yarns of polyester fibers with yarns of glass fibers to form a composite fabric. The fabric is then fitted within a mold and soaked with resin. The formed fabric and resin composition is then allowed to harden within the mold. While providing a generally rigid structure, such a technique includes a number of limitations, among them the inability to produce a variety of different shapes of substantial bulk or complex dimensions.

Another prior art technique involves manufacturing a light weight energy-absorbing structure made up of a laminate including a plurality of fabrics. The fabrics are pre-impregnated with a thermosetting resin and abutted against a core of cellular foam which has had a bonding material applied at the interface between the impregnated fabric and the foam. Heat is applied to cure the resin and the bonding material. However, when bonding material is used, it is often the case in hostile environments that the bonding material breaks down, an undesirable result when such structures are used in high load or stress applications.

Yet still another prior art technique involves the manufacture of a thermoformable composite article comprised of a core layer made of a synthetic resin foam. A pair of adhesive layers are placed in contact with the opposite upper and lower surfaces of the core layer and a pair of fabric layers are superimposed on the opposite upper and lower surfaces of the core layer. The fabric layers are bonded to the core layer by the adhesive layers. At least one of the fabric layers is made of a non-woven fabric which has been impregnated with a thermoplastic or thermosetting resin. This technique also involves the disadvantages noted above with respect to the use of adhesives.

In boat building, especially glass fiber boats, hulls are typically reinforced by a grid arrangement of structural members known as "stringers" and "bulkheads," hereafter collectively referred to as "stringers." Present boat-building technology typically employs plywood stringers, although a growing percentage uses glass fiber/foam stringers. The plywood stringer system involves several process stages.

The plywood is first cut to shape by a cutter or by hand with the use of templates. The stringer system which is commonly made up of interlocking stringers and bulkheads is assembled outside of the boat, with interlocking pieces being held with staples. Once the system is assembled, it is then placed in a boat as a module and laminated into place using a combination of reinforcing fabrics.

Glass fiber stringers are installed in a slightly different manner from plywood stringers. One way of installing such stringers is to cut blocks of foam into the shape of the stringers. The stringer shaped foam is then bonded into the hull and covered with glass fiber. Another way is that the glass fiber shell of the stringer is first laminated using a male mold. The stringer is then ground to fit into the boat and once the stringer has been ground to fit, it is spaced off of the bottom of the boat to avoid cracking problems. The stringer is then laminated into place and holes are drilled into the stringer and the stringer is filled with a two-part urethane foam.

Future boat construction is expected to use closed molding technologies. The reason for this is 1) to control noxious vapor emissions into the environment, 2) to reduce labor costs and (3) to create structurally superior constructions. Such future technology will generally require use of stringer systems made of composite structures compatible with such closed moldings. Conventional stringer systems are not well suited to such technologies since they will need to be installed after the hull has been laminated using an open mold. Wood stringers would be difficult to incorporate into a closed mold due to height and width constraints. Further, repositioning of glass fiber reinforcement normally hand laminated over the wood or foam stringer system would be costly and create quality control problems. Conventional glass fiber stringers also pose problems due to the void in the stringer structures. Specifically, since foam is injected into such stringer after installation, it becomes difficult to keep the resin from filling the inside of the stringer.

Another problem which frequently occurs in the construction of composite articles such as boats arises in connection with the assembly of inner and outer plastic or composite shells. For example, in the case of boat manufacturing, it is conventional to first form a hull portion and to subsequently attach a deck portion therein. However, due to manufacturing tolerances and the need to securely bond the two structures together, caulking of various types is conventionally applied in heavy concentration at locations along the inner hull and on the underside of the deck where the two shells are intended to be joined together. When the deck is installed within the hull, the excess caulking is displaced and the caulking which remains fills any gaps and crevices between the two components. Thus, the caulking has the effect of filling gaps between the hull and deck and securely bonding the two together over the entire bonding area.

There are two serious drawbacks to the conventional use of caulking to assemble boats. One problem is the amount of weight which the caulking adds to a boat. In fact, such caulking can represent roughly 5% to 10% of the total weight of conventionally manufactured boats. A further problem is the labor involved in applying the caulking. The task tends to be exceptionally labor intensive and time consuming.

In accordance with the invention, these and other problems with the prior art are avoided by providing a resilient composite structure which avoids the use of adhesive and lends itself to a variety of shapes, structures and applications. In one specific aspect, the composite articles manu-

factured in accordance with the method are used as resilient attachment members in boat manufacturing to greatly simplify the manufacture of boats, and permitting their use in closed mold environments.

SUMMARY OF THE INVENTION

The invention comprises a method for manufacturing a composite structure having an exposed reinforcing fabric layer free of structural foam and curable resin. The method comprises the steps of attaching a reinforcing fabric layer to a fabric layer on one side thereof; arranging the attached fabric layers in a configuration constrained against outward movement and with the fabric layer facing inwardly and defining a cavity between opposing surfaces thereof; dispensing a predetermined amount of a self-expanding, self-curable, uncured resilient structural foam into the cavity; allowing the foam to expand and cure in the cavity at a molding pressure determined by the predetermined amount of foam and thereby attaching itself to the fabric layer to form the composite structure. The molding pressure causes the expanding foam to substantially fill only interstices of the fabric layer, without substantially penetrating the reinforcing fabric layer. After the foam has cured, the composite structure is freed from the constraint of the arranging step. The reinforcing fabric layer of the composite structure is thereafter substantially completely saturatable with a curable material for lamination to another structure in a subsequent processing step. The method can further comprise the step of laminating the cured composite structure to another composite structure by saturating the outer portion of the fabric layer or the reinforcing fabric layer of the cured composite structure with a curable resin.

In an alternative embodiment, the invention concerns a method for making a similar resilient composite structure, which has only a single outer fabric layer. The alternative embodiment comprises the steps of: arranging a fabric layer in a configuration constrained against outward movement and defining a cavity between opposing surfaces of the fabric layer; dispensing a predetermined amount of a self-expanding, self-curable, uncured resilient foam into the cavity. Permitting the foam to expand and cure in the cavity at a molding pressure determined by the predetermined amount of the foam and to thereby attach itself to the fabric layer to form the resilient composite structure. The molding pressure causes the expanding foam to substantially fill only interstices of an inner portion of the fabric layer, without substantially penetrating an outer portion of the fabric layer. Once the foam has cured, the composite structure is freed from the constraint of the arranging step, with the outer portion of the fabric layer of the composite structure being thereafter substantially completely saturatable with a curable material for lamination to another structure in a subsequent processing step.

The method according to the invention further includes a process for manufacturing a composite article comprising first and second interfitting plastic shells, by utilizing the resilient composite structure. The process involves the steps of: positioning at an attachment point within the first plastic shell a resilient foam core composite structure as described herein; saturating the reinforcing fabric layer with a curable plastic resin; positioning the second plastic shell on the first plastic shell so that the resilient composite structure contacts an attachment point of the second plastic shell and is compressed between the plastic shells; and allowing the plastic resin to cure. In one embodiment, the attachment points of the first and second plastic shells are separated by a gap, and the gap is substantially filled by the resilient composite structure when the completed composite article is assembled.

The method can further comprise the step of selecting the fabric layer to be composed of a continuous thermoplastic fiber needle punched together, a polyester staple mat, a glass fiber mat, an organic fiber mat or fabric, and an inorganic fiber mat or fabric.

The method can further comprise the step of selecting the flexible structural foam to be composed of an open cell urethane foam, foam rubber, or any one of a variety of other flexible foams which are self expanding as part of the curing process. One example of such a foam is a two part product available from BASF Corporation comprised of BASF Product Code designations NB8009-7-132 (resin part) and WUC3164T (isocyanate part).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial, side cross-sectional view of a composite structure in accordance with the invention;

FIG. 2 is a block diagram showing the sequence of steps of making the composite structure in accordance with the method of the invention;

FIG. 3 is a block diagram showing a sequence of steps illustrating the method of manufacturing boats using the composite structure in accordance with the invention as stringers for the hull of the boat;

FIG. 4 is an end, cross-sectional view of a typical stringer construction made according to the method of the invention; and

FIG. 5 is an end, cross-sectional view of an alternative embodiment to the stringer shown in FIG. 4, which omits the reinforcing fabric layer.

FIG. 6 is a block diagram showing a pressurized foam injection system having a time variable dispensing control system.

FIG. 7 is a block diagram showing a sequence of steps of making the composite structure in accordance with an alternative method of the invention.

FIG. 8 is a block diagram showing a sequence of steps of making the composite structure in accordance with a second alternative method of the invention.

FIG. 9 is a cross-sectional view of a composite article comprising two composite shell members in position for attachment to one another.

FIG. 10(A) is an enlarged view of a resilient composite component in FIG. 9, just prior to assembly of the two composite shell members.

FIG. 10(B) is an enlarged view of the resilient composite component in FIG. 10(A) after the two composite shell members are assembled to one another.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates a typical construction for a composite structure **11** in accordance with the invention. The structure **11** is made up of a reinforcing fiber layer **13**, preferably a directional reinforcing fiber layer of organic or inorganic structural reinforcing fibers such as glass fiber, carbon fibers, aramid fibers such as is available under the name Kevlar, linear polyethylene or polypropylene fibers such as is available under the name Spectra, or polyester fibers. By reinforcing fiber is meant a fiber which when added to a composite material enhances the structural properties of the material. The fibers can be randomly oriented, or preferentially, they can be oriented in one or more directions. While a number of specific types of materials have been

given for use as the reinforcing fiber layer, it will be appreciated by those of ordinary skill in the art that other equivalent-type reinforcing fiber layers can be employed in the practice of the invention.

The fiber layer **13** is attached to a fabric layer **15** which has a large number of interstices or pores **19**. The fabric layer **15** is preferably a non-woven fabric composed of continuous thermoplastic fiber, needle punched together to yield a felt like fabric. One example of such a fabric is Trevira Spunbond, which is commercially available from Hoechst Celanese Corporation. However, the invention is not limited in this regard and the fabric layer **15** may be comprised of other materials, including polyester staple mat and glass fiber mat, as well as other organic and inorganic fiber mats and fabrics.

Preferably, the reinforcing fiber layer **13** and fabric layer **15** are secured to each other mechanically. Such mechanical attachment is typically done by conventional stitching **17**. Other means of attachment, as noted previously, include alternatives such as needle punching, stapling or buttons. In the case of certain non-hostile environment applications even adhesives can be used.

A structural foam **21** is attached to the fabric layer **15** by having penetrated into the interstices **19** at penetration region **23** of the foam **21** during the manufacture of the structure **11**. Preferably the foam is a self-expanding, self-curing urethane foam which has been caused to expand at region **23** into the interstices **19** of fabric layer **15** by having been filled into a mold in an amount sufficient to cause pressure as a result of expansion of the foam **21** to penetrate at region **23** into the interstices **19** of the fabric layer **15**.

The interaction between the foam **21** and fabric layer **15** provides a number of mechanical advantages over other structures. More specifically, the low density urethane foams used in the practice of the invention typically have tensile strengths of about 50 pounds per square inch (psi) with an elongation of under 7%. When such a foam is expanded into a non-woven fabric, the mechanical properties of the fabric/foam system increases significantly. In the case where the fabric used is a continuous filament needle punched thermoplastic polyester fabric such as Trevira Spunbond, the mechanical properties of the Trevira/foam system increases to around 2,000 to 3,000 psi, with an elongation of over 20%. All of these non-woven fibers are typically non-woven organic or inorganic fiber mat, for example, polyester, fabrics of conventional construction.

The method of making the composite structure in accordance with the invention is illustrated in FIG. 2. In a first step **25** the fabric layer **15** is attached to the reinforcing fabric layer **13**. Preferably such attachment is done by stitching. Alternatively, as noted previously, the fabrics can be secured to each other by means of needle punching, staples or buttons or other mechanical technologies sufficient to secure one fabric to the other. After attaching the two layers of fabrics together, the attached layers are laid in a mold at a step **27** with the layer **15** facing the inside of the mold.

At step **29** a self-expanding, self-curing structural foam is prepared/mixed. Typically, such a self-rising, self-curing foam is a urethane foam commercially available from BASF, MOBAY, PPG and is typically an MDI-based rigid polyurethane foam (methylene-diphenyl-methane diisocyanate) using "hydrogenated chlorofluorocarbons" (HCFC), water and/or CO₂ as a blowing agent. The mold is then filled with the self-expanding and self-curing structural foam at step **31** in an amount sufficient to allow for expansion of the foam after the mold is closed. This generates enough pressure so

that the foam penetrates into the interstices **19** of the fabric layer **15**. On average, enough foam is added to generate pressures of about 5–18 "pounds per square inch" (psi), at a minimum 5 psi, and at an optimum pressure of 10 psi.

Different mold pressure may be used, however, and upper pressure limits are dictated primarily by mold strength. For a given mold pressure, foam amounts and thickness of the non-woven layer can be adjusted so that mold completely fills with the foam, but the foam does not penetrate through the reinforcing layer. The mold is closed at step **33** and the foam is allowed to cure and expand therein. At step **35** the formed article is then removed after curing.

FIG. 6 shows a foam dispensing system for a two-part, self-expanding, self-curing foam which can be utilized for an alternative method according to the present invention as shown in FIGS. 7 and 8. The foam-dispensing system **56** includes storage tanks **57**, **59** for separately storing the constituent materials which comprise the self-expanding, self-curing foam. The constituent foam materials are forced under pressure through hoses **61**, **63** to nozzle **65**. Nozzle **65** is provided for mixing the constituent materials necessary to form the self-expanding, self-curing foam, and dispensing said foam in a controlled manner. Nozzle **65** includes one or more valves to control dispensing of foam, which valves may be controlled by a timing device **67**. Timing device **67** may be pre-set to cause the valves associated with nozzle **65** to open for a pre-determined duration, and thereby dispense a precisely-determined mass of self-expanding, self-curing foam.

An alternative method of making the composite structure in accordance with the present invention is illustrated in FIG. 7. In a first step **67**, the fabric layer **15** is attached to the reinforcing fabric layer **13**, as previously described. After attaching the two layers of fabric together, the attached layers are laid in a mold at a step **69** with the fabric layer **15** facing the inside of the mold.

At step **71**, the foam-dispensing system is prepared to dispense self-expanding, self-curing structural foam. In this step, timing device **67** is preset to open the valves in nozzle **65** for a predetermined dispensing time, so that the foam-dispensing system releases a predetermined mass of foam upon command. At step **73**, the foam-dispensing system is caused to fill the mold with self-expanding, self-curing structural foam. If the timing device for the foam-dispensing system has been preset, the mold will be filled with a precise amount of foam corresponding to the dispensing time set on the timing device **67** in step **71**. At step **75**, the mold is closed and the foam allowed to cure and expand. Finally, at step **77**, the formed article is removed after curing.

A second alternative method of making the composite structure in accordance with the invention is illustrated in FIG. 8. Steps **79**, **81** and **83** in FIG. 8 are identical to steps **67**, **69** and **71**, respectively, in FIG. 7, except that the mold is provided with a foam injection port to allow foam into the interior of the mold. The foam injection port may be comprised of any suitable opening formed in a wall of the mold or a mechanical fitting capable of allowing the passage of foam into the mold. If the injection port is comprised of a simple opening, it is preferably located on an upper area of the mold, such as the mold lid, to prevent foam from escaping as the mold is filled. An opening is cut in the attached layers where they cover the injection port to allow the passage of foam through the attached layers.

At step **85**, rather than filling an open mold with self-expanding foam, the attached fabric layers are positioned on the mold lid, so that the woven fabric layer faces the lid, and

the non-woven layer faces inside of the mold when the lid is closed. After the lid has been closed in step **85**, the foam-dispensing system is activated in step **87** so that self-expanding, self-curing structural foam is dispensed into the mold through the injection port. If the timing device for the foam-dispensing system has been pre-set, the mold will be filled with a precise amount of foam corresponding to the dispensing time set on the timing device **67**. At step **89**, the foam is allowed to cure and expand. Finally, at step **91**, the cured structural preform is removed from the mold.

With regard to the method of FIGS. **7** and **8**, the precise mass of foam dispensed into the mold and the pre-set dispensing time set on the timing device for controlling said volume, are preferably determined experimentally to achieve penetration of said foam into the non-woven layer, but not into the woven layer of the attached fabric layers. The mold structure must be designed to withstand the pressure generated by the expanding foam. Typically, foam pressure may range from 5 to 18 psi.

In the method according to FIGS. **2**, **7** and **8**, one or more overflow ports can be provided on a portion of the mold to release excess foam, and limit foam pressure within the mold to a range of between 5 to 18 psi. The overflow port is preferably located on an upper area of the mold such as the mold lid. This placement prevents foam from escaping when the mold is initially filled, and permits foam to escape only after it has begun to expand. The overflow port can be comprised of a simple opening cut in a wall of the mold. Alternatively, a suitable fitting may be used which passes through a mold wall, and allows excess foam to escape the interior of the mold. If such overflow ports are used, a hole is cut in the attached fabric layers where they pass over the overflow port to allow the foam to escape the interior of the mold as it expands under pressure. In the method according to FIG. **8**, the foam injection port can also serve as an overflow port. The size and number of the overflow ports are preferably determined experimentally to ensure that when excess foam has been added to a mold, the foam does not penetrate through the reinforced fabric layer.

The articles manufactured in accordance with the method of the invention can be molded in a variety of different shapes and applied in a number of different technologies. One specific application for the articles is in the boat building industry wherein the articles can be shaped as stringers to replace conventional wood stringers or glass fiber stringers used in the manufacture of glass fiber boats. The use of stringers in accordance with the practice of the invention results in a modular approach to boat manufacturing that saves the boat builder time and money, particularly for small boats. More specifically, conventional stringer systems take approximately six man hours to install. Stringers manufactured in accordance with the method of the invention require approximately twenty to forty man minutes to install on a cured hull. If the stringer system of the invention is installed and wet out with resin while the hull laminate resin is still "wet," i.e., uncured, molding time can also be significantly reduced. Thus, the process reduction results in substantial cost savings and decreased mold cycle times.

The stringers in accordance with the structure of the invention are especially adapted for use in boat construction. Typically, open-molded boat construction begins with a gel coat being first sprayed into a mold. Once the gel coat has cured, a skin coat consisting of chopped strand mat or chopped roving, woven roving or stitch bonded glass fiber is laid on the cured gel coat layer. This will result in the structural layer of the boat. Typically, such a layer is then

impregnated with a resin and allowed to cure to form the structural layer, and the stringers are laid therein after curing.

In accordance with the method of the invention as illustrated in FIG. **3**, the gel coat is first sprayed at step **37** into a boat-hull mold and allowed to cure. The structural glass fiber is layered at step **39** in the same manner as in conventional boat construction. In a preferred aspect, the stringers are then installed at step **41**, preferably with the layer of structural glass fiber having been impregnated and the stringers having been impregnated with a setting resin. At step **47** the installed stringers are then cured along with the structural layer, and at step **49** the boat hull is then removed from the mold.

In an alternative implementation, the structural glass fiber is initially cured at a step **43** and thereafter at step **45** a light layer of chopped glass fiber is added at the locations where the stringers are to be installed. In this alternative, the light layer of chopped glass fiber is impregnated with resin and the stringers are impregnated with resin and then installed. The entire system is then allowed to cure. The process follows thereafter the same as with the initially described process with reference to FIG. **3**.

A number of advantages result in construction in accordance with the above-described system. First, as illustrated in FIG. **4**, it will be appreciated that a stringer **51** in accordance with the structure of the invention can be made with rounded corners **53** which results in reduced stress on the cured glass woven fiber **13** as implemented in use in boat construction because resin impregnated cured glass fiber generally weakens at sharp corners. The appropriate shape of a mold in making the structure **11** of the invention can avoid such sharp corners. Optionally, to provide increased strength and toughness to the urethane foam **21**, an additional layer **15a** of non-woven fabric can be attached to the lid of the mold to ensure that the fabric becomes secured to the foam at a region wherein the reinforcing fabric **13**, i.e., glass fiber, is not required. As noted previously, the use of the fabric layer interfaced with the foam **21** provides increased structural properties.

A lower strength, alternative embodiment of a composite structure **90** is shown in FIG. **5**, wherein only the fabric layer **15** is utilized, without the reinforcing layer **13**, as in the bottom of the stringer shown in FIG. **4**. In this embodiment, and in accordance with an inventive arrangement, a predetermined amount of a self-expanding, self-curable, uncured structural foam is dispensed into the cavity **21**. The foam expands and cures in the cavity at a molding pressure determined by the predetermined amount of the foam and thereby attaches itself to the fabric layer to form the composite structure. The molding pressure causes the expanding foam to substantially fill only interstices **19** of an inner portion **91** of the fabric layer, without substantially penetrating an outer portion **92** of the fabric layer. An illustrative border between the inner and outer portions is represented by a jagged dashed line **93**. After freeing the cured composite structure from the constraint of the arranging step, the outer portion **92** of the fabric layer of the composite structure is substantially completely saturable with a curable material for lamination to another structure in a subsequent processing step. Such other structure may include, for example, spas, baths, shower enclosures and the like. The composite structure in accordance with this inventive arrangement is especially adapted for use in lower stress environments than such composite structure technology has generally been applied to in the past. Significantly, however, it can be adapted for use in applications requiring higher strength. For

example, if the composite structure is used as a structural reinforcing component, additional layers of reinforcing fabric may be laminated over the basic composite structure to enhance its strength.

While the invention has been described with reference to its use as stringers or bulkheads for boats, it will be appreciated by those of ordinary skill in the art that other uses can be made of the composite structures in accordance with the invention. For example, such structures can be used as reinforcing elements for automobile body parts such as hood and trunk lids, bumper beams and structural framing. Likewise, another use can be in architectural applications where the structures could be integrated into panel fabrication processes as structural ribs or stiffeners.

In an alternative embodiment, resilient stringer components may be manufactured in accordance with the invention. In this embodiment, the injected foam is chosen to have flexible and resilient characteristics when cured. Examples of such foams include a flexible or open cell urethane foam, foam rubber, or any one of a variety of other flexible foams which are self expanding as part of the curing process. One example of such a foam is a two part product available from BASF Corporation comprised of BASF Product Code designations NB8009-7-132 (resin part) and WUC3164T (isocyanate part). However the invention is not limited in this regard and it will be appreciated that any other material may also be used, provided that it can be injected into a cavity, subsequently expand so as to penetrate the non-woven fiber layer and change state to a resilient material.

In other respects the manufacturing process is the same as previously described herein with respect to FIGS. 1-8. Resilient stringer components thus formed have an exposed layer of fabric or reinforcing fabric as shown and described with respect to FIGS. 4 and 5. The stringer components thus formed are particularly suitable for manufacturing composite articles comprised of two or more shell members as shall now be described in relation to FIGS. 9 and 10.

FIG. 9 shows a two part composite article prepared for further assembly wherein a first composite shell 104 will be positioned within composite shell 102. In the example shown, the composite resin and fiber shells are configured in the shape of a boat deck and hull portion, respectively. However, it should be understood that the invention is not limited in this regard, and can be used in connection with any composite article comprised of two or more components which are required to be joined together. As shown in FIG. 9, resilient stringer components 110, formed in accordance with the invention as described above, are positioned at attachment points 108 on the composite shell 102. In a preferred embodiment, flaps 112 may be provided to extend over a portion of the attachment point 108.

When the shell 104 is ready to be positioned within shell 102, the outer exposed outer layer 114 of the resilient stringer component 110 is saturated with uncured curable resin. Thereafter, when the two shells are joined together, manufacturing and design tolerances will typically result in a varying amount of distance between the attachment points 108 on the shell 102 and attachment points 106 on the shell 104. However, as shown in FIGS. 10(a) and (b), the resilient stringer components 110 positioned between the attachment points 106, 108 will be compressed therebetween. The amount of compression experienced by each resilient stringer component will depend upon the size of the gap between each of the attachment points 106, 108. Once the two shells are positioned together, the resin applied to the exposed layer of fabric or reinforcing fabric 114 is allowed

to cure and harden. The resulting structure is securely bonded together with the space between the attachment points filled by the resilient stringer components 110.

It will be appreciated that the resilient stringer components may be attached to either of shells 104, 102 prior to the two shell being positioned together. Attachment points 106, 108 may be designed to project slightly from the surface of the shell as shown or not, depending on the particular application. Likewise, the attachment points 106, 108 can be either integrally formed with the shell or may be separately formed structural members which have been bonded thereto.

The resilient stringer components as disclosed herein are especially adapted to use in blind bonding situations, i.e. those instances where the form of two or more composite shell members renders the attachment point between them inaccessible once the two composite shells are assembled. In such instances, workers cannot examine the closeness of the fit or customize the fit to adjust for manufacturing or design tolerances simply because the bonding site is inaccessible. However, by using the resilient stringer components as disclosed herein, a proper fit can be assured regardless of accessibility of the bonding site, and without the need for large amounts of putty to fill any gaps.

Although particular preferred embodiments of the invention have been disclosed in detail for illustrative purposes, it will be recognized that variations or modifications of the disclosed invention, including the use of additional layers of fabric, alternative types of self-expanding foam, and various alternative adhesive or synthetic resins, lie within the scope of the present invention.

What is claimed is:

1. A method of making a resilient composite structure having an exposed reinforcing fabric layer free of structural foam and curable resin, said method comprising the steps of:

attaching a reinforcing fabric layer to a non-woven fabric layer on one side thereof;

arranging said attached fabric layers in a configuration constrained against outward movement and with the non-woven fabric layer facing inwardly and defining a cavity between opposing surfaces thereof;

dispensing a predetermined amount of a self-expanding, uncured resilient structural foam into said cavity, said foam expanding and curing in said cavity at a molding pressure determined by said predetermined amount of said foam and thereby attaching itself to said non-woven fabric layer to form said composite structure, said molding pressure causing said expanding foam to substantially fill only interstices of said non-woven fabric layer, without substantially penetrating the reinforcing fabric layer; and,

freeing said cured composite structure from said constraint of said arranging step, said reinforcing fabric layer of said composite structure, upon being freed from said constraint, being substantially completely saturatable with a curable material for lamination to another structure in a subsequent processing step.

2. The method of claim 1, further comprising the step of laminating said cured resilient composite structure to a larger composite structure by saturating said reinforcing fabric layer of said cured composite structure with a curable resin.

3. A method for making a resilient composite structure comprising the steps of:

arranging a fabric layer in a configuration constrained against outward movement and defining a cavity between opposing surfaces of said fabric layer;

11

dispensing a predetermined amount of a self-expanding,
 self-curable, uncured resilient structural foam into said
 cavity, said foam expanding and curing in said cavity at
 a molding pressure determined by said predetermined
 amount of said foam and thereby attaching itself to said
 fabric layer to form said composite structure, said
 molding pressure causing said expanding foam to sub-
 stantially fill only interstices of an inner portion of said
 fabric layer, without substantially penetrating an outer
 portion of said fabric layer; and,
 freeing said cured resilient composite structure from said
 constraint of said arranging step, said outer portion of

12

said fabric layer of said composite structure, upon
 being freed from said constraint, being substantially
 completely saturable with a curable material for lami-
 nation to another structure in a subsequent processing
 step.

4. The method of claim 3, further comprising the step of
 laminating said cured composite structure to another com-
 posite structure by saturating said outer portion of said fabric
 layer of said cured composite structure with a curable resin.

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